EVALUATION OF THE SAFETY PERFORMANCE OF EJECTION SEAT CUSHIONS

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ABSTRACT

Several operational and prototype ejection seat cushions were selected for the evaluation of their performance for the prevention and reduction of spinal injuries. The evaluation was performed using impact tests on the vertical deceleration tower, where a cushion was placed between the seat pan and the occupant (a 50th percentile Hybrid III manikin) and was subjected to +Gz impact at 8, 10, and 12 g, respectively. For comparison, tests were also conducted on a bare seat pan without a cushion. Based on the test data, analyses were performed to determine the dependency of certain occupant responses and structural responses on the cushions. The cushions were ranked in the sequences illustrating their performance merit in terms of the peak values of the lumbar force and other responses.

INTRODUCTION

Chronic back pain in military pilots is a significant problem. It may be caused by any combination of the following factors: aircraft vibration, pilot posture during aircraft control, pilot muscle fatigue, cockpit ergonomics, and the pilot's general physical fitness and medical history. High-technology improvements in occupant comfort have limited application to military aircraft seats, especially ejection seats, as they are an integral part of an aircraft life support system. The introduction of any complicated system or additional parts to enhance comfort would require extensive integration and qualification efforts at considerable cost. Therefore, the solutions for comfort that can be quickly and cheaply implemented are desired.

Long-term sitting comfort may be enhanced by a new or improved seat cushion. However, some seat cushions have been shown to amplify the acceleration transmitted to the torso of the aircrew member if they have not been designed properly.[1] Any item introduced to an ejection seat and located between the seat pan and the glutial region of the pilot must not compromise the existing risk of spinal injury which is limited by the human tolerance to the fracture of the lumbar vertebra. As more resources are applied to improving seat cushion comfort, the performance of a cushion for the prevention and reduction of spinal injuries (the safety performance) should not be ignored or sacrificed. Therefore, when the comfort performance of a cushion design is assessed, its safety performance must also be evaluated.

The safety performance of a cushion can be measured by certain spinal injury criteria, such as Dynamic Response Index (DRI), or directly by certain occupant response characteristics, such as the peak lumbar load and the peak chest acceleration.[2,3] The evaluation of the safety performance of ejection seat cushions is conventionally performed using impact tests. A number of vertical deceleration tower (VDT) test studies have been performed at the Air Force Research Laboratory (AFRL) over decades to evaluate several types of ejection seat cushions, including certain designs with comfort improvement.[1,4-9] It should be pointed out that in the previous study, some inconsistencies in the lumbar load data were noted.[1]

A number of cushion designs with new materials and configurations have been introduced recently for the improvement of comfort. In this study, several ejection seat cushions including operational and prototype were selected for the evaluation of their safety performance. They included the Aces II, Contour C47, Confor C45, Confor C47, Foam C47, Helmis/Poly, and Fr 70 cushions. The evaluation was performed through impact tests where the cushions were subjected to +Gz impact. The tests were conducted on the VDT at the AFRL.

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EXPERIMENT DESIGN

Test Facility and Set-Up

The AFRL vertical deceleration tower facility is shown in Figure 1. It is composed of two vertical rails and a drop carriage. Guided by the rails, the carriage is allowed to enter a free-fall state from a pre-determined drop height. A plunger mounted on the rear of the carriage is guided into a cylinder filled with water located at the base and between the vertical rails. A +Gz acceleration pulse (actually a deceleration pulse) is produced and applied to the carriage when water is displaced from the cylinder by the plunger. The pulse shape is controlled by varying the drop height, which determines the peak acceleration level or G level, and by varying the shape of the plunger, which determines the rise time of the pulse. A carriage-mounted seat is used to restrain a test subject (human or manikin) in an upright seated position. The carriage, impact seat, and test subject are instrumented with load cells or accelerometers to collect dynamic response data.

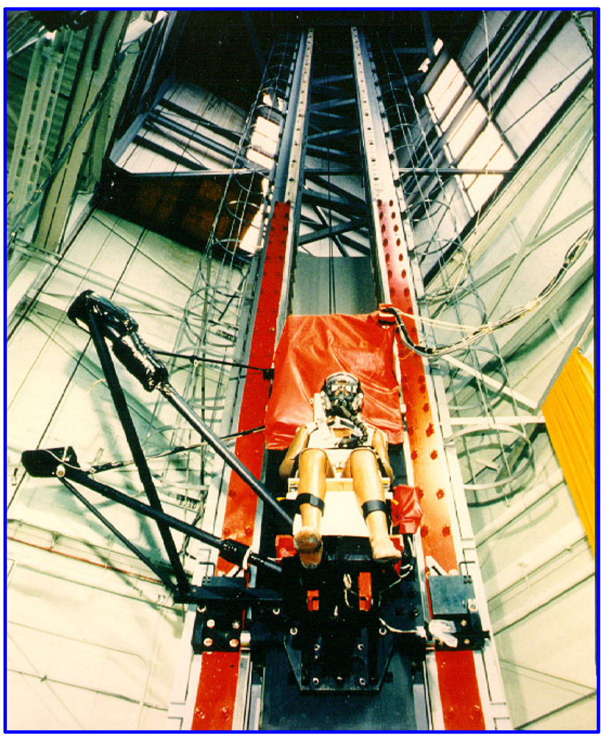

Figure 1. VDT test set-up

A modified ACES II F-16 ejection seat was used for the tests. The seat back was cut away from the seat and mounted to the VDT carriage so that the seat back tangent plane was vertical. The seat pan was mounted to the horizontal surface of the VDT carriage so that the seat pan was perpendicular to the seat back tangent plane.

A 50% Hybrid III manikin was used as the occupant in the tests. The manikin was dressed in a standard flight suit and wore a HGU-55/P flight helmet. The manikin was seated in an upright position, centered in the seat, and restrained using the seat's restraint system. A standard double shoulder strap and a lap belt assembly were used as the restraint system for the occupant. The pre-tension levels of the restraint system were 20 ± 5 lbs. Limb restraints were also applied to restrain the motion of the occupant's arms and legs.

Test Matrix

The test matrix is shown in Table 1. Each cushion was tested at three G-levels: 8, 10, and 12 g ($g = 9.8\,\text{m/s}^2$), which were the nominal amplitudes of carriage acceleration pulse. The test cells included the scenario where the occupant was seated on the bare seat pan without a cushion. The test for each cell was repeated three times. The acceleration pulse for the VDT was approximately a half-sine waveform, with the amplitude of 8, 10, and 12 g, respectively, and a rise-time of approximately 80 ms.

Table 1. Test Matrix

Cell	G-level	CUSHION
A	8	None
B	8	ACES II
C	8	Contour C47
D	8	Confor C45
E	8	Confor C47
F	8	Foam C47
G	8	Hemis/Poly
H	8	FR 70
I	10	None
J	10	ACES II
K	10	Contour C47
L	10	Confor C45
M	10	Confor C47
N	10	Foam C47
O	10	Hemis/Poly
P	10	FR 70
Q	12	None
R	12	ACES II
S	12	Contour C47
T	12	Confor C45
U	12	Confor C47
V	12	Foam C47
W	12	Hemis/Poly
X	12	FR 70

Data Collection

The accelerations and forces at a number of locations of the test system were recorded, which included the accelerations of the carriage, seat pan, and seat cushion, the forces on the seat pan, and the forces at the restraint system attachment points. The measurements of the occupant responses included the accelerations of the lumbar, chest, and head, and the forces on the femur, lumbar, and head.

TEST RESULTS AND ANALYSIS

The data from the tests can be found in the AFRL/HE Biodynamics Data Bank[1] with the study number of 200203. The test results showed that the repeatability is sound with small variations among the three tests for each cell. The statistic analysis is neither meaningful as the sample size of three is too small nor necessary as the test conditions are well controlled and the random factors are not significant. Therefore, the average of the three tests is used to represent the result for each cell.

For the VDT tests, the acceleration pulse of the carriage is the impact input. It was controlled with respect to its amplitude (peak) and rise-time in the tests. Given the nominal amplitude for each G-level, the actual amplitude has small variations for different cushions, as shown in Table 2.

In the vertical deceleration tower tests, the occupant was seated in an upright position. Consequently, the responses in the vertical direction (Z-axis) are dominant as compared to those in the horizontal directions (X- and Y-axis). Therefore, in the following analysis, only vertical responses are considered.

The time histories of the accelerations of the carriage, seat pan, lumbar, chest, and head, and the lumbar force are displayed in Fig. 2. The peak values of the accelerations of carriage, seat pan, seat cushion, lumbar, chest, and head, and the peak values of the lumbar force and the seat pan force are determined from the test data and are given in Table 2 (a)-(c) for three different impact levels, respectively.

The relationship between the system input (the carriage acceleration) and the system output (the responses of the seat pan, seat cushion, and occupant) can be analyzed based on their peak values. A quantity, which is called as impact transmissibility, can be used to represent this relationship, which is defined as

$$T = \frac{\text{Peak}\{\text{Response}\}}{\text{Peak}\{\text{Carriage Acceleration}\}} \tag{1}$$

where the unit is lb for the force responses and g for the acceleration responses. The calculated values of the impact transmissibility from the carriage to the occupant and from the carriage to the seat pan and seat cushion are given in Tables 3 and 4, respectively.

DISCUSSION

Safety Performance and Merit

The performance of a cushion for the prevention and reduction of spinal injuries can be measured by the spinal injury criteria, among which the maximum lumbar load in the vertical direction will be employed in this paper. The peak values of lumbar force for each cushion at three impact levels are shown in Figure 3. With a given threshold for the spinal injury risk, a judgment whether a cushion is safe or not can be made based on these values. All tested cushions were deemed safe for the threshold value of the lumbar force equal to 1500 lbs, according to the values given in Table 2 for the prescribed impact levels.

Figure 3 and Table 3 show that the differences among the tested cushions are large in terms of their peak lumbar forces. This means that the cushions have different safety margins (the difference between the safety limit and the peak value), which is important when impact levels exceed the prescribed ranges. This margin represents the safety merit of a cushion and thus should be evaluated.

In order to be independent of the impact level, the safety merit of a cushion can be assessed in terms of its impact transmissibility from the carriage acceleration to the lumbar force, which is given in Table 3 and illustrated in Figure 4. In Table 5, the values of the impact transmissibility are sorted from the smallest to the largest so that the cushions are arranged in a sequence from the best to the worst for each impact level, in terms of their safety merit.

Based on Table 5, several observations can be made:

- The impact transmissibility of a cushion is not a constant. For all tested cushions, it increases as the impact levels increase. This means that the mechanical behavior of these cushions is nonlinear.
- The cushion sequences in terms of safety merit are slightly different for the three impact levels. The rank of a cushion in the three sequences may vary.

[1]http://www.biodyn.wpafb.af.mil

- Overall, in terms of the safety merit, Foam C47 and Confor C45 are the best; Aces II and Contour C47 are the worst; and the others are between.
- When the occupant was seated on the bare seat pan without a cushion, the impact transmissibility increased with the increase of the impact levels.

Influences on Occupant's Other Responses

The other occupant responses to be considered include the accelerations of the lumbar, chest, and head, as displayed in Figure 2. The influences of the cushion type (materials and configurations) on these responses can be analyzed based on the impact transmissibility from the carriage to respective responses given in Table 3. As the values of the impact transmissibility are sorted from the smallest to the largest, the cushions are arranged in a sequence from the best to the worst for each impact level, as shown in Table 6.

Note that:
- For each occupant response, the cushion sequences for the three impact levels are slightly different.
- At the same impact level, the cushion sequences for the three responses have large differences.
- Overall, in terms of the accelerations of the lumbar, chest, and head, the responses produced by Foam C47, Confor C45, and Confor C47 are smaller, whereas those resulting from Aces II and Contour C47 are larger.

The comparison of Table 5 with Table 6 indicates that the cushion merit sequence according to the peak lumbar force and those determined based on the other three responses are not in agreement, but the differences are small. This means that the acceleration of the lumbar, chest, or head cannot completely be used as a substitute for the lumbar force as a criterion for evaluating spinal injury risk. However, if a cushion has the optimal performance for the reduction of the peak lumbar force, it could have good, if not the best, performance for the reduction of the maximum accelerations of the lumbar, chest, and head.

Influences on Structural Responses

The structural responses being considered are the seat pan force and the accelerations of the seat pan and seat cushion. The dependency of these responses on the cushions can be analyzed based on the impact transmissibility of them given in Table 4. The cushions are sorted according to their values of transmissibility and arranged in the sequences from small values to large ones. The results are shown in Table 7. Note that in the no-cushion cases, the accelerometer, which was placed on the top of a cushion to measure the cushion acceleration for the cases with cushions, was placed on the top of the seat pan. Therefore, the seat cushion acceleration for the no-cushion cases was actually the acceleration on the top of the seat pan.

The impact input to the seat cushion is the seat pan acceleration. Due to the resilience of the structural connection between the carriage and the seat pan, the carriage acceleration and the seat pan acceleration were different. As shown in Figure 2, the seat pan acceleration had some oscillations. The amplitude of the carriage acceleration was amplified, for which one factor is the resilience of the structural connection, as indicted by the values given in Table 4 for no-cushion cases. However, the amplitude amplification also depends on the cushions. This is because the occupant, as a subsystem, is coupled to the seat pan through the seat cushion. According to the values given in Table 4, Foam C47, Confor C45, and Confor C47 have smaller transmissibility values, whereas Aces II and Contour C47 have larger ones.

Therefore, if the structural connection between the carriage and the seat pan is not rigid or the discrepancy between the carriage acceleration and the seat pan acceleration is significant, it is not appropriate to take the seat pan acceleration as the input reference and to evaluate the safety performance of cushions based on it. As shown in Tables 5 and 8, the variation of the values of the impact transmissibility from the seat pan acceleration to the lumbar force is smaller than the variation of the values from the carriage acceleration to the lumbar force; the cushion merit sequences for both cases are not quite agreeable. This means that the effects of the cushion on the seat pan response should be taken into account.

The seat pan force represents the global dynamic response of the seat-occupant system. It also depends on the cushions. According to the values given in Table 4, the variation of the impact transmissibility for the seat pan force is large. By comparing Tables 5 and 7, it can be seen that the cushion merit sequences according to the peak lumbar force and those sorted by the seat pan force are not fully agreeable. However, basically, the seat pan force increases (decreases) as the lumbar force increases (decreases), as indicated by Table 2.

The seat cushion acceleration is the impact input to the occupant, which depends upon the mechanical properties of a cushion and determines the dynamic responses of

the occupant. The impact transmissibility from the carriage to the seat cushion depends on the cushions, as shown by the values given in Table 4. The cushion merit sequences sorted according to the seat cushion acceleration are not agreeable with those sorted according to the lumbar force, as can be seen from the comparison of Tables 5 and 7. This means that the peak value of the seat cushion acceleration cannot be used for the evaluation of the cushion safety performance. The occupant in the VDT tests (manikin or human subject) is a complicated biomechanical system. The impact dynamic response of the occupant depends on the entire set of characteristics of the impact input rather than on its amplitude only.

Acceleration Amplitude Amplification

It was reported that the seat cushion would amplify the acceleration transmitted from the seat pan.[1] However, in this study, it was found that the acceleration amplitude may be decreased or increased when it comes from the seat pan through the seat cushion, depending on each cushion, and either the decrease or the increase is small, as shown in Table 8. This discrepancy between the two test studies needs more investigation.

Cushion Material and Configuration

Note that Confor C47 and Contour C47 are constructed of similar materials, but Contour C47 has a sculpted geometry for the improvement of comfort. However, their safety performances are different: Confor C47 has a safety merit 5-10% lower than Contour C47 while the lumbar loads for Contour C47 can be 10-20% higher. This suggests that the cushion safety margin depends on not only the cushion material but also the cushion configuration. In fact, in Contour C47, some areas of the cushion are thinner than others, thus less energy absorption is present and bottom-out may occur sooner in those areas. This exemplifies the need for balanced development to include all aspects of the cushion utilization.

CONCLUSIONS

The impact transmissibility from the carriage acceleration to the lumbar force depends on the cushions. It is not a constant and varies with impact levels. Whereas all tested cushions were deemed safe in terms of the peak lumbar force with the threshold value equal to 1500 lbs, Foam C47, Confor C45, and Confor C47 have the largest safety performance margin whereas Aces II and Contour C47 have the least.

The acceleration responses of the lumbar, chest, and head also depend on the cushions. The dependency varies slightly with the impact levels. The cushion merit sequences sorted according to the peak values of these responses are not fully agreeable with those determined by the peak lumbar force. This means that neither of these responses can completely substitute the peak lumbar force as a measure of spinal injury risk. However, if a cushion has the best performance for the reduction of the peak lumbar force, it could have fairly good, if not the best, performance for the reduction of the accelerations of the lumbar, chest, or head.

The amplitude could be amplified when the acceleration pulse is transmitted from the carriage to the seat pan due to the resilience of the structural connection between them. The amplification also depends on the cushions. Therefore, if the connection between the carriage and the seat pan is not rigid, the evaluation of a cushion should be based on the carriage acceleration rather than the seat pan acceleration.

Basically, the seat pan force increases or decreases with the increase or decrease of the lumbar force. A cushion may decease or increase the amplitude of the acceleration transmitted from the seat pan through the cushion. The cushion safety margin depends on the cushion material as well as the cushion configuration.

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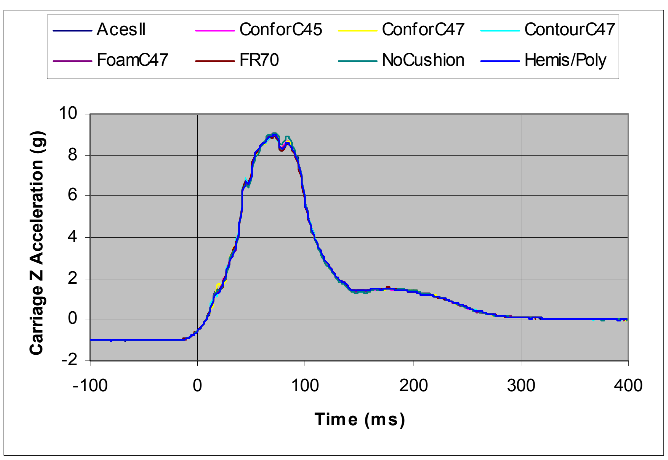
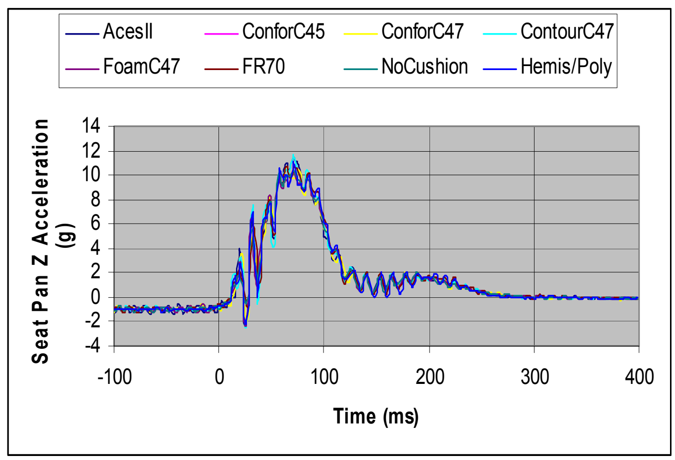
Biography

Dr. Zhiqing Cheng is a mechanical engineer at Advanced Information Engineering Services, A General Dynamics Company, supporting biodynamics programs for the Air Force Research Laboratory/Human Effectiveness Directorate (AFRL/HE) at Wright-Patterson Air Force Base (WPAFB). His areas of work and research involve bio-computational mechanics, impact dynamics modeling and simulation with finite element and rigid multi-body programs, optimization, wavelets, and vibration.

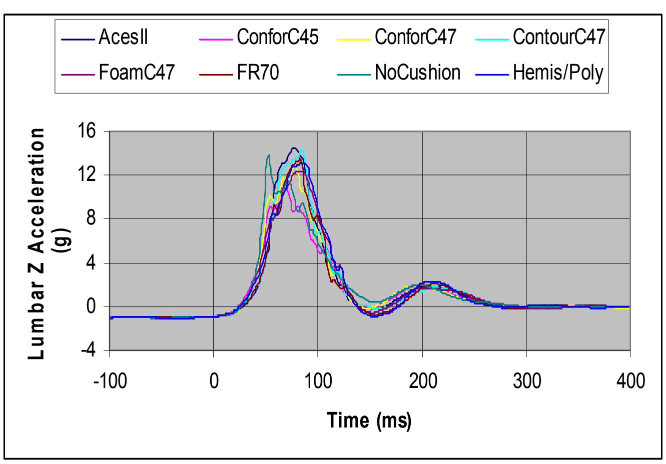
Dr. Joseph A. Pellettiere is a mechanical engineer for the Biomechanics Branch, Human Effectiveness Directorate, Air Force Research Laboratory. He has a BS in Biomedical Engineering and an MS in Mechanical Engineering from Case Western Reserve University, and a Ph.D. in Mechanical Engineering from the University of Virginia. His experience is in biomechanics, human simulation and injury, crash protection and prevention using both testing and computational technologies. He currently leads the modeling simulation group in the branch.



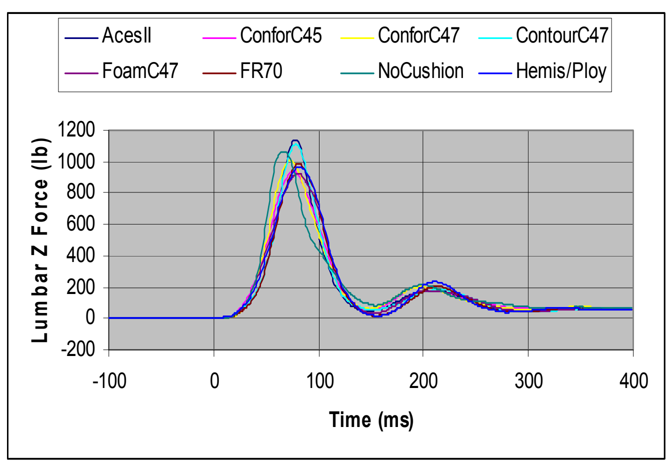
(a) Carriage z acceleration



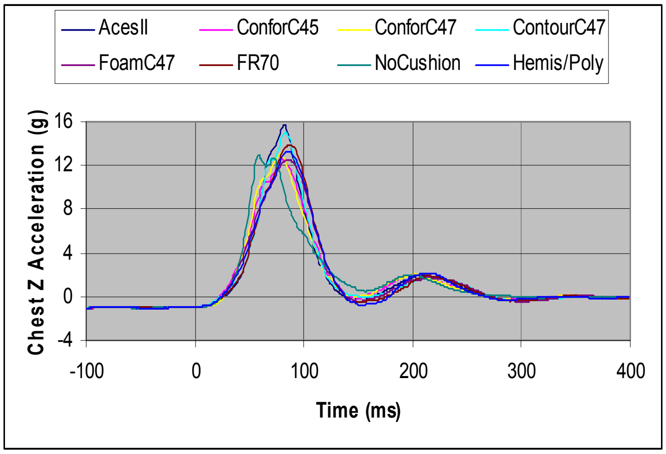
(b) Seat pan z acceleration



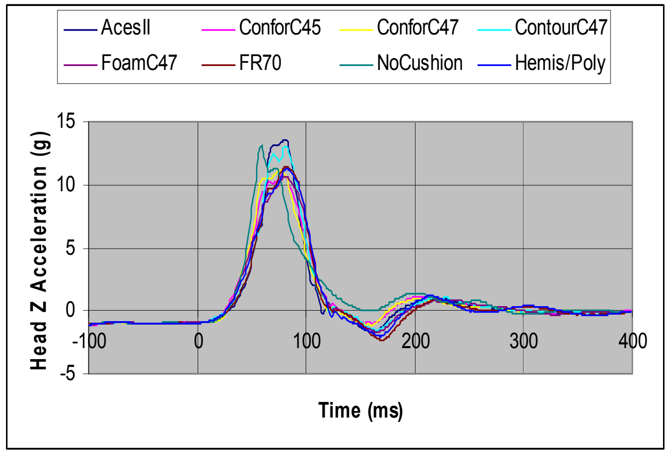
(c) Lumbar z acceleration



(d) Lumbar z force



(e) Chest z acceleration



(f) Head z acceleration

Figure 2. Time histories of accelerations and force for the impact of 10 g

Table 2a. Peak values for the impact of 8 g

	CARRIAGE Z ACCEL (G)	SEAT PAN Z ACCEL (G)	CUSHION Z ACCEL (G)	LUMBAR Z ACCEL (G)	CHEST Z ACCEL (G)	HEAD Z ACCEL (G)	LUMBAR Z FORCE (LB)	SEAT PAN Z FORCE (LB)
None	8.05	9.38	8.43	10.93	10.62	10.44	714.54	1988.38
Aces II	7.87	9.57	10.00	12.00	12.00	10.87	792.21	2302.12
Contour C47	7.85	9.43	10.49	11.72	12.53	10.63	797.37	2396.52
Confor C45	8.05	8.99	9.04	10.07	10.17	9.10	666.12	2015.91
Confor C47	8.07	9.10	9.05	10.43	10.76	9.58	719.41	2085.84
Foam C47	8.02	9.10	9.49	10.52	10.66	9.31	665.73	2056.78
Hemis/Poly	7.92	9.23	9.66	10.62	11.41	9.56	697.57	2186.19
Fr 70	7.93	9.46	9.84	11.11	11.16	9.61	699.01	2159.95

Table 2b. Peak values for the impact of 10 g

	CARRIAGE Z ACCEL (G)	SEAT PAN Z ACCEL (G)	CUSHION Z ACCEL (G)	LUMBAR Z ACCEL (G)	CHEST Z ACCEL (G)	HEAD Z ACCEL (G)	LUMBAR Z FORCE (LB)	SEAT PAN Z FORCE (LB)
None	10.13	12.08	10.99	15.37	13.88	14.33	1001.84	2763.77
Aces II	9.91	12.59	13.25	15.51	16.62	14.60	1090.74	3084.67
Contour C47	9.92	12.61	13.19	15.27	16.02	14.05	1053.52	3055.49
Confor C45	10.05	11.50	11.20	11.87	13.63	11.95	882.43	2610.57
Confor C47	10.05	11.76	11.59	13.95	14.08	12.21	949.94	2730.50
Foam C47	10.07	11.59	12.00	13.38	13.49	11.62	871.64	2630.66
Hemis/Poly	9.99	12.07	12.13	14.18	14.28	12.23	922.90	2712.19
Fr 70	9.93	11.68	13.35	14.49	14.84	12.40	941.41	2803.91

Table 2c. Peak values for the impact of 12 g

	CARRIAGE Z ACCEL (G)	SEAT PAN Z ACCEL (G)	CUSHION Z ACCEL (G)	LUMBAR Z ACCEL (G)	CHEST Z ACCEL (G)	HEAD Z ACCEL (G)	LUMBAR Z FORCE (LB)	SEAT PAN Z FORCE (LB)
None	11.84	14.55	13.39	19.62	18.16	17.78	1292.86	3412.37
Aces II	11.83	15.38	16.16	18.89	20.60	17.62	1317.91	3834.55
Contour C47	11.84	15.23	15.78	19.62	20.46	17.76	1291.98	3797.15
Confor C45	12.02	14.33	14.19	16.97	17.22	14.72	1110.19	3383.36
Confor C47	12.11	14.17	13.85	16.36	16.57	14.44	1116.69	3286.42
Foam C47	12.07	14.16	14.82	17.58	17.64	14.87	1072.50	3376.38
Hemis/Poly	12.01	14.81	15.23	17.83	18.57	15.33	1148.09	3462.31
Fr 70	11.98	14.67	15.55	18.69	18.43	15.20	1156.20	3411.87

Table 3. Impact transmissibility from the carriage to the occupant

	Lumbar-F/Carriage-A (lb/g)			Lumbar-A/Carriage-A (g/g)			Chest-A/Carriage-A (g/g)			Head-A/Carriage-A (g/g)		
	8 g	10 g	12 g	8 g	10 g	12 g	8 g	10 g	12 g	8 g	10 g	12 g
None	88.72	98.91	109.15	1.36	1.52	1.66	1.32	1.37	1.53	1.30	1.42	1.50
Aces II	100.63	110.05	111.41	1.52	1.56	1.60	1.52	1.68	1.74	1.38	1.47	1.49
Contour C47	101.59	106.25	109.12	1.49	1.54	1.66	1.60	1.62	1.73	1.35	1.42	1.50
Confor C45	82.79	87.85	92.35	1.25	1.18	1.41	1.26	1.36	1.43	1.13	1.19	1.22
Confor C47	89.14	94.50	92.24	1.29	1.39	1.35	1.33	1.40	1.37	1.19	1.21	1.19
Foam C47	82.98	86.59	88.83	1.31	1.33	1.46	1.33	1.34	1.46	1.16	1.15	1.23
Hemis/Poly	88.12	92.40	95.57	1.34	1.42	1.48	1.44	1.43	1.55	1.21	1.22	1.28
Fr 70	88.16	94.83	96.52	1.40	1.46	1.56	1.41	1.50	1.54	1.21	1.25	1.27

Table 4. Impact transmissibility from the carriage to the seat pan and seat cushion

	Pan-F/Car-A (lb/g)			Pan-A/Carriage-A (g/g)			Cushion-A/Carriage-A (g/g)		
	8 g	10 g	12 g	8 g	10 g	12 g	8 g	10 g	12 g
None	246.87	272.86	288.10	1.16	1.19	1.23	1.05	1.08	1.13
Aces II	292.42	311.22	324.17	1.22	1.27	1.30	1.27	1.34	1.37
Contour C47	305.33	308.15	320.71	1.20	1.27	1.29	1.34	1.33	1.33
Confor C45	250.55	259.89	281.43	1.12	1.14	1.19	1.12	1.12	1.18
Confor C47	258.43	271.62	271.47	1.13	1.17	1.17	1.12	1.15	1.14
Foam C47	256.37	261.35	279.66	1.13	1.15	1.17	1.18	1.19	1.23
Hemis/Poly	276.17	271.53	288.22	1.17	1.21	1.23	1.22	1.21	1.27
Fr 70	272.43	282.44	284.82	1.19	1.18	1.22	1.24	1.34	1.30

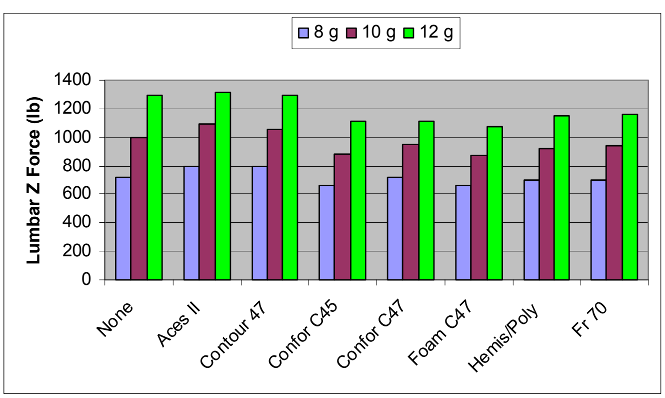


Figure 3. Peak lumbar z force

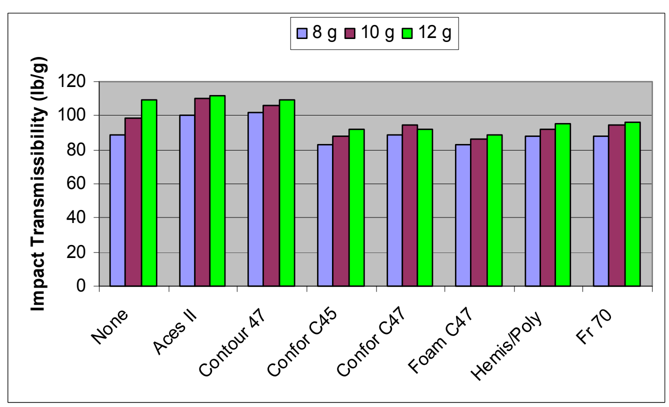


Figure 4. Impact transmissibility from carriage to lumbar

Table 5. Safety merit according to impact transmissibility

8 g		10 g		12 g	
Confor C45	82.79	Foam C47	86.59	Foam C47	88.83
Foam C47	82.98	Confor C45	87.85	Confor C47	92.24
Hemis/Poly	88.12	Hemis/Poly	92.40	Confor C45	92.35
Fr 70	88.16	Confor C47	94.50	Hemis/Poly	95.57
None	88.72	Fr 70	94.83	Fr 70	96.52
Confor C47	89.14	None	98.91	Contour C47	109.12
Aces II	100.63	Contour C47	106.25	None	109.15
Contour C47	101.59	Aces II	110.05	Aces II	111.41

Table 6. Effects on other occupant responses

Lumbar Acceleration			Chest Acceleration			Head Acceleration		
8 g	10 g	12 g	8 g	10 g	12 g	8 g	10 g	12 g
Confor C45	Confor C45	Confor C47	Confor C45	Foam C47	Confor C47	Confor C45	Foam C47	Confor C47
Confor C47	Foam C47	Confor C45	None	Confor C45	Confor C45	Foam C47	Confor C45	Confor C45
Foam C47	Confor C47	Foam C47	Foam C47	None	Foam C47	Confor C47	Confor C47	Foam C47
Hemis/Poly	Hemis/Poly	Hemis/Poly	Confor C47	Confor C47	None	Hemis/Poly	Hemis/Poly	Fr 70
None	Fr 70	Fr 70	Fr 70	Hemis/Poly	Fr 70	Fr 70	Fr 70	Hemis/Poly
Fr 70	None	Aces II	Hemis/Poly	Fr 70	Hemis/Poly	None	None	Aces II
Contour C47	Contour C47	None	Aces II	Contour C47	Contour C47	Contour C47	Contour C47	Contour C47
Aces II	Aces II	Contour C47	Contour C47	Aces II	Aces II	Aces II	Aces II	None

Table 7. Effects on the responses of seat pan and seat cushion

Seat Pan Force			Seat Pan Acceleration			Seat Cushion Acceleration		
8 g	10 g	12 g	8 g	10 g	12 g	8 g	10 g	12 g
None	Confor C45	Confor C47	Confor C45	Confor C45	Confor C47	None	None	None
Confor C45	Foam C47	Foam C47	Confor C47	Foam C47	Foam C47	Confor C47	Confor C45	Confor C47
Foam C47	Hemis/Poly	Confor C45	Foam C47	Confor C47	Confor C45	Confor C45	Confor C47	Confor C45
Confor C47	Confor C47	Fr 70	None	Fr 70	Fr 70	Foam C47	Foam C47	Foam C47
Fr 70	None	None	Hemis/Poly	None	None	Hemis/Poly	Hemis/Poly	Hemis/Poly
Hemis/Poly	Fr 70	Hemis/Poly	Fr 70	Hemis/Poly	Hemis/Poly	Fr 70	Contour C47	Fr 70
Aces II	Contour C47	Contour C47	Contour C47	Aces II	Contour C47	Aces II	Aces II	Contour C47
Contour C47	Aces II	Aces II	Aces II	Contour C47	Aces II	Contour C47	Fr 70	Aces II

Table 8. Impact transmissibility from the seat pan to the seat cushion and lumbar

Seat Cushion Accel. vs. Seat Pan Accel.						Lumbar Force vs. Seat Pan Accel.					
	8 g		10 g		12 g		8 g		10 g		12 g
None	0.90	None	0.91	None	0.92	Foam C47	73.18	Foam C47	75.24	Foam C47	75.74
Confor C47	0.99	Confor C45	0.97	Confor C47	0.98	Fr 70	73.88	Hemis/Poly	76.49	Confor C45	77.49
Confor C45	1.01	Confor C47	0.99	Confor C45	0.99	Confor C45	74.08	Confor C45	76.72	Hemis/Poly	77.52
Fr 70	1.04	Hemis/Poly	1.01	Hemis/Poly	1.03	Hemis/Poly	75.58	Fr 70	80.58	Confor C47	78.82
Foam C47	1.04	Foam C47	1.04	Contour C47	1.04	None	76.17	Confor C47	80.75	Fr 70	78.83
Aces II	1.04	Contour C47	1.05	Foam C47	1.05	Confor C47	79.04	None	82.96	Contour C47	84.83
Hemis/Poly	1.05	Aces II	1.05	Aces II	1.05	Aces II	82.78	Contour C47	83.52	Aces II	85.68
Contour C47	1.11	Fr 70	1.14	Fr 70	1.06	Contour C47	84.60	Aces II	86.66	None	88.83